Submission 14

Weight of evidence for passage, transport, extra mortality, and aggregate hypothesis

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The document discusses the weights of three of critical hypotheses in the spring chinook analysis relationship between fish travel time and survival, the effectiveness of transportation and the extra mortality and evaluates the two aggregate hypotheses: strong-hydro related and a weak-hydro related. The approach is to describe the essential mathematical relationships of the hypotheses and then discuss them in terms of the four weighting criteria: clarity, mechanisms, empirical evidence and validity in prospective analyses. It also discusses two aggregate hypotheses: the strong-hydro hypothesis and the weak-hydro hypothesis.

1. Passage Mortality Hypotheses

The most significant determinant of the outcomes of recovery actions is the choice of the smolt passage survival hypothesis. The most significant difference between the CRiSP and FLUSH models involves how the rate mortality changes as fish move through the river (Fig. 1). In CRiSP the rate of mortality is essentially constant over time while in FLUSH the rate of mortality increases the longer fish are in the river. Consequentially, a change in travel time has greater effect on the survival in FLUSH than in CRiSP. In the upper reaches of the river CRiSP and FLUSH predict similar mortalities but as fish move down river the two models diverge because the rate of mortality in FLUSH increases while in CRiSP remains essentially constant. Also illustrated is the FLUSH curve with the two low flow years (1973, 1977) removed.
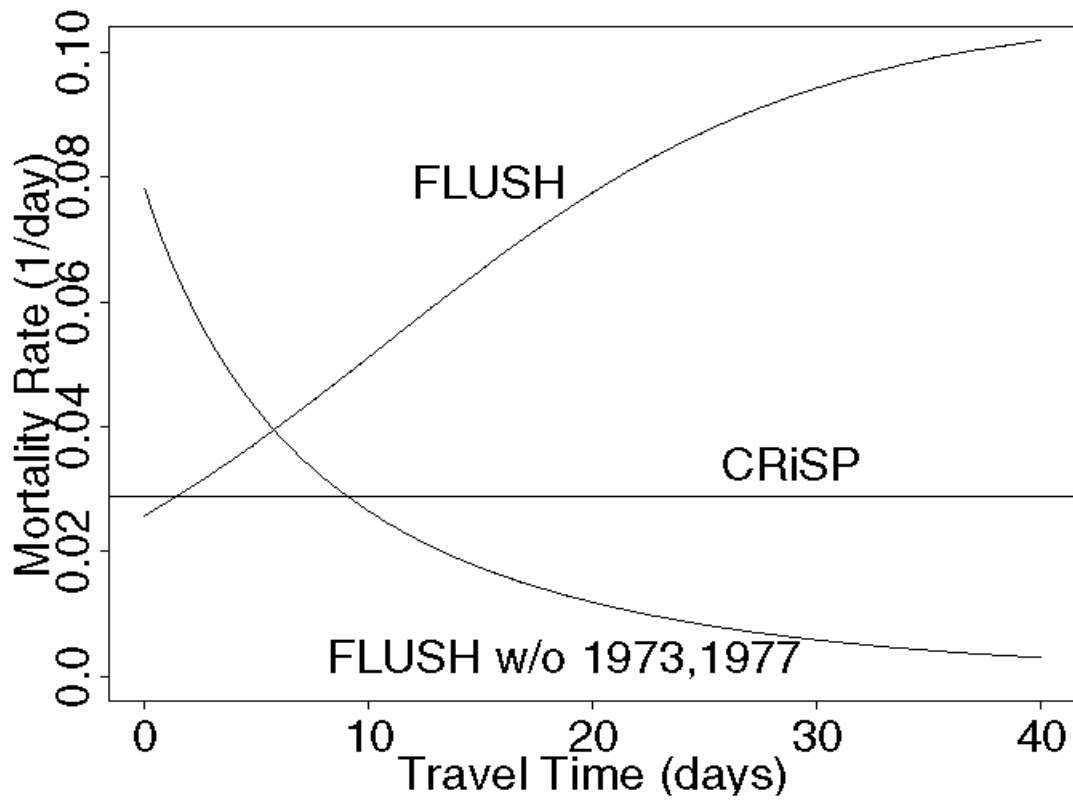
Fig. 1 Rate of in-river passage mortality in the CRiSP and FLUSH passage models (a) using data 1970-1996 (b) excluding 1973 & 1977.

The basic forms of in-river survival in CRiSP and FLUSH models can be expressed

CRiSP survival equation $V_n(t) = \exp(-C\,t)\,S_{dam}{}^N$.

FLUSH survival equation $V_n(t) = ((1+A)/(A + \exp(B\,t)))\,S_{dam}{}^N$.

where Vn(t) is the survival of smolts passing through the hydrosystem, S_{dam} is the survival in passing a dam, N is the number of dams fish pass and the coefficients A, B and C describe the reservoir survival of the two models as a function of fish travel time through the hydrosystem, t. In these reduced forms the effects of predators, temperature and total dissolved gas levels in CRiSP combine into an exponential coefficient C. In a similar manner the A and B coefficients characterize all factors which affect the relationship between travel time and survival in FLUSH. The travel time itself is similar in the two models so the differences in the outcomes of actions A2 and A3 for FLUSH and CRiSP are the result of the two forms of survival with travel time. Model coefficients used in this analysis were $S_{dam} = 95\%$, A = 14.07, B = 0.182 (Marmorek et al 1996) [Note recent model coefficients for the FLUSH model were requested but have not to date been provided] and C = 0.027 calculated from CRiSP model runs (Hayes and Anderson 1998). The percent mortality per day, or rate of mortality, r , for each model is illustrated in Fig. 1 and comes from the equation

CRiSP Mortality rate $= d\,V_n/dt = -r\,V_n$.

The essential rate term for each model system can be expressed

CRiSP Mortality rate r = C.

FLUSH Mortality rate $r = A/(1 + A\,\exp(-B\,t))$.

Clarity of hypothesis

FLUSH: Assumes that the average rate of reservoir survival depends on exposure time through the river. The form of the model was an "upside-down logistic" (PATH document 1996 Chapter 6 appendix 5 section 6.). The criteria for the equation were that survival equals one at time equals zero and that it fit the 1970 through 1980 Sims and Ossiander, after removing the dam passage mortality. In the PATH 1996 document the turbine mortality was 15% and spill mortality was 2%. In later PATH analysis (February 1987) different turbine mortality values were used which gave different values of the model coefficients A and B, but the assumption of increasing mortality rate was unchanged. That is, other model forms were not explored with different assumptions on the level of dam passage mortality.

CRiSP: Assumes the average rate of mortality is constant with time giving an exponential survival function (Anderson et al. 1996, Hayes and Anderson 1998).

In essence, the interpretation of the causes of very low passage survivals in the 1973 and 1977 distinguish the travel survival relationship of the two models. The FLUSH model associates the low survivals with long travel times and assumes a fundamental strong relationship between travel time and passage survival for all other years, past and future. The CRiSP model associates the low survivals with documented poor dam passage conditions in the 1970s and assumes an exponential relationship between travel time and survival for past and future conditions.

Weight of mechanism evidence

The increasing mortality rate hypothesis of FLUSH is based on fitting historical data contingent on assumptions of dam passage mortality. The resulting Òupside-down logisticsÓ equation is unique to ecology. No similar relationships or biological evidence have been cited. The CRiSP model assumes a standard exponential equation, which for example is the basis of Ricker spawner recruitment relationship. In this relationship the average rate of mortality is constant giving an exponential survival relationship over time. Variations in the rate of mortality depend on water temperature and gas levels but these factors do not alter the basic relationship.

In FLUSH fish traveling together will have different rates of mortality if they were release at different locations and times. This produces strong differences between fish and indeterminacy for fish released at the top of the hydrosystem. To illustrate the problems consider the 1996 FLUSH model detailed above, which is essentially the model under TURB 1 assumptions. If Snake River smolts take 10 days to reach McNary Dam and 8 additional days to reach Bonneville Dam, FLUSH predicts a 40% survival for the stock between McNary and Bonneville. But in comparison smolts released at McNary Dam and traveling with the Snake fish experience a 68% survival. The significantly lower survival of the Snake stock, traveling side-by-side the McNary stock, is a consequence of the travel time-mortality rate relationship in FLUSH. It requires that the longer fish are in the river the greater their mortality. A biological mechanism that imposes such a strong effect on mortality, is to the best of my knowledge, unknown and unobserved.

FLUSH, conditioning the mortality rate on the past history, also has a significant conceptual problem in defining survival of wild fish from the head of Lower Granite pool. Since fish from different locations have different travel times to the head of the pool, FLUSH violates its survival relationship and assumes that time in river is not a factor above the top of the pool while it is below. This indeterminacy results in a problem in defining survival in drawdown where the fish may have significantly different travel times reaching the first dam in a drawdown scenario.

In comparison, the CRiSP model does not have problems of indeterminacy conditioned on the past history, since the mortality rate is independent of past history. In CRiSP, stocks from different origins traveling together in the lower river have equivalent survivals: 66% over the McNary to Bonneville reach. The CRiSP mortality relationship is based on the classical ecological assumption that the instantaneous rate of mortality is independent of the past history and to a first order can be expressed as a constant.

Weight of empirical evidence

Comparison of the models to survival data given in Table 4.4 of the Weight of Evidence report (July 3 1998) is irrelevant because the FLUSH model was calibrated to this. Note CRiSP, which fits the data equally well as FLUSH did in its calibration, was calibrated independent of the data used to calibrate FLUSH. To test the validity of the two models, they need to be compared to data not used in calibration. Such data, representing survival estimates above and below the river location used for FLUSH calibration, are available.

The result of the comparison of the models to survival data in river reaches shorter than the reaches used in the FLUSH calibration is illustrated in Fig. 2. PIT tag data for the years 1994-1996 for the reach from Lower Granite Dam tailrace and Lower Monumental Dam tailrace are illustrated. The FLUSH model predicts a strong travel time survival relationship which does not comport with the flat response of the data. The CRiSP model predicts a weak relationship that is closer to the observed flat response. The CRiSP 1.6 model, which contains a more mathematically robust survival relationship but is not available at this time for PATH, has a flatter travel-time survival relationship and it closer to the data than CRiSP1.5 used in the current PATH analyses.
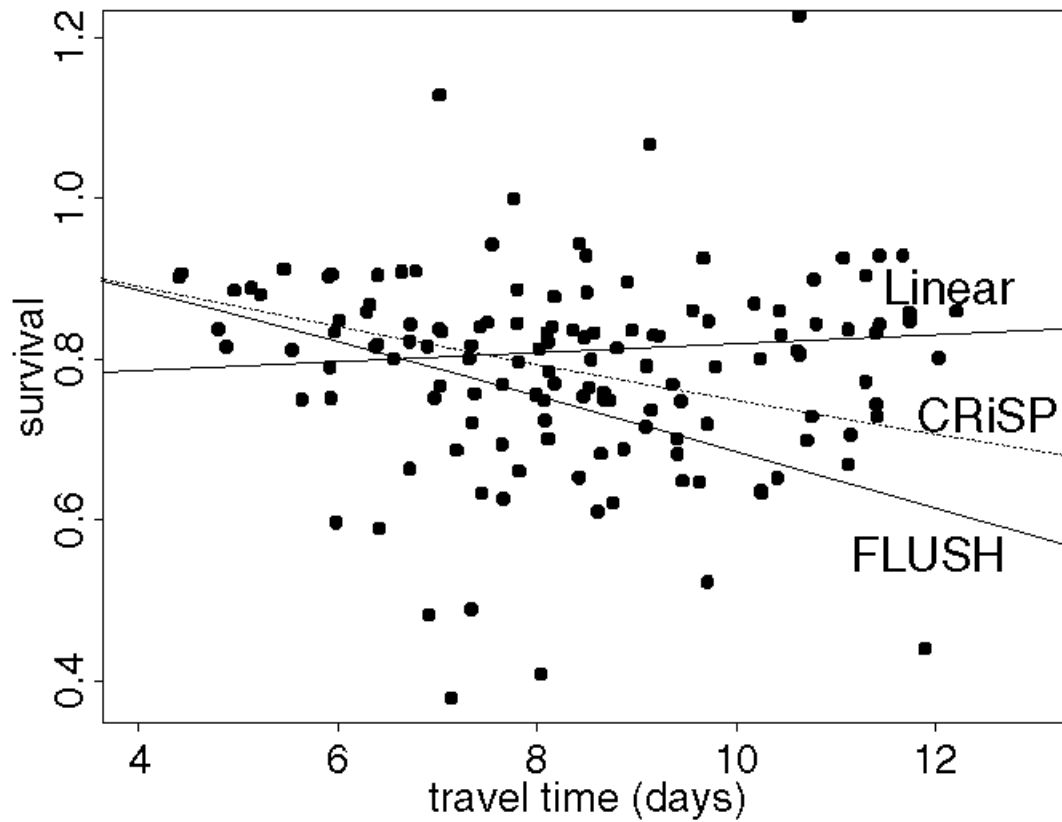
Fig. 2 Comparison of travel time survival relationships between
Lower Granite tailrace and Lower Monumental tailrace for PIT
tag data collected in 1994, 95 and 96 (Smith et al 1997).
Predicted relationships using models is expressed by the
essential equation described above and a linear regression.

Since the FLUSH relationship is strongly driven by the two low flow years, a second comparison is to explore the significance of these years to the FLUSH model. Using these two years is problematic because they are the only two significant outliers from suite of survival estimates dating back to 1966. They have fish travel times nearly twice other years, survivals 4 to 8 times lower and reviews of the data have identified significant dam passage problems in these years (Stewart 1994, Williams and Matthews 1995). To illustrate the significance of these two years to FLUSH a recalibration of the Sims and Ossiander was done with and without 1973 and 1977. Without the two years the data has no trend (Table 1). Also note that the standard error in the regression with the two years is very large so the function has a large uncertainty. In comparison CRiSP was not calibrated with the survival data, but removing the two years from the regression does not affect the fit r-squared = 0.85 with under TURB4 and 0.8x with the two years removed.

Table 1 FLUSH model parameters for TURB 1 and 4 with and without the 1973 and 1977 data.

TURB 1: Data: 1970 through 1996   Rsquared 0.485

	Value	Std. Error	t value
A	3.1411	5.85071	0.5368
B	0.1066	0.07654	1.3925

Data: 1970 through 1996   excluding 1973 −1997   Rsquared 0.081

	Value	Std. Error	t value
A	-2.11885	1.5155	-1.3980
B	-0.08044	0.1883	-0.4269

TURB4: Data: 1970 through 1996   Rsquared 0.294

	Value	Std. Error	t value
A	30.6798	75.340	0.4072
B	0.1895	0.1459	1.2989

Data: 1970 through 1996   excluding 1973-1997   Rsquared 0.057

	Value	Std. Error	t value
A	5.45701	25.8399	0.2111
B	0.08996	0.2048	0.4391

A third evaluation is to compare model predicted survivals to the survivals over long reaches not used in the calibrations. Available estimates include survivals to McNary dam in 1992 and estimates of survival to Bonneville Dam in 1997 and 1998. CRiSP estimates of survivals over these reaches were provided for a comparison by NMFS. Survival from the Lower Granite tailrace to the forebay of Bonneville dam was estimated by CRiSP to be 48.5% in 1997 and 55% in 1998.

A fourth approach is to take a closer examination of the Sims and Ossiander data used to derive the form of the mortality rate equation in FLUSH. The assumed mortality rate function was derived using only the data over the longest reach in the data set (mostly the Dalles Dam) and, as was demonstrated in the second comparison, this is highly dependent on years 1973 and 1977. A closer look at the data shows that, in fact, survival over the river was opposite to the assumed trend. Survival to the midpoint, Ice Harbor dam, was lower (36%) than survival from Ice Harbor to the Dalles (58%) (Raymond 1979). According to the FLUSH hypotheses the opposite pattern exists.

Weight of prospective projections

The FLUSH model's strong relationship between travel time and survival is highly dependent on the assumption that the low survivals in 1973 and 1977 are a result of long travel times and that this relationship also implies a concomitant improvement in survival at short travel times. The evidence is does not support this hypothesis.

The CRiSP models considers the two low flow years abnormal because of documented high levels of descaling, abnormal hydro operations and observed passage mortality (see PATH February 1998, Appendix A page 65). The final result is that CRiSP says the extremely high mortality was due to dams passage conditions in specific years, principally associated with high trash levels, and that the underlying travel time survival relationship for all years is weak. For example a 50% mortality at Little Goose dam was noted in 1972 1973 (Raymond 1979). In FLUSH under TURB 1 this mortality is 70% of this passage mortality is attributed to the reservoir instead.

The passage models are highly significant to prospective analysis. CRiSP says drawdown and the resulting decease in fish travel time will have little impact on survival compared to what is achieved with transportation. FLUSH says that a strong travel time survival relationship will be realized with drawdown and this will compensate for the lost benefits of transportation. In addition, the passage models are important to the hydro related extra mortality hypothesis which amplifies the assumptions of travel time and survival from the passage models. These hypotheses combined in the aggregate hypothesis make the passage model hypotheses the dominant determinants of the probabilities of meeting jeopardy and survival standards. This multiplicative effect of the passage models under the hydro related hypothesis is illustrated in the discussion of the aggregate hypotheses.

The assumption of a strong travel time survival relationship in FLUSH is essentially based on data from years of two of long travel times and documented adverse dam passage conditions. Projecting benefits of using drawdown to shorten the travel time more than has been

measured is problematic at best and assumes that the model is valid outside the range of observations which the model poorly fits.

Table 2 Summary of passage model evaluations J. Anderson.

Model	FLUSH		CRiSP	
Hypothesis	Average mortality rate increases with travel time		Average mortality rate constant	
Clarity	mortality rate increases because of stress in passage but hypothesis only is expressed in travel time and is independent of dams.	4	mortality rate independent of exposure time and dams. This is clearly expressed by the hypothesis	1
Mechanism	the Òup-side-down logistic equationÓ has no clear biological basis and produces wide differences in survival for different stocks.	4	uses the exponential survival function which is the basis of fisheries models	2
Evidence	evidence does not support the strong mortality rate function.	4	evidence indicates the exponential survival function underestimates survival	2
Validity of Projection	projecting a strong benefit of shorter travel times is problematic given the lack of mechanism and evidence	4	projecting a weak effect of shorter travel times is supported by the evidence	2

2. Transport Survival Hypotheses

In PATH, hypotheses on the survival of transported fish after they are released below Bonneville dam were specific to each passage models. That is, the CRiSP transport hypothesis was not combined with the FLUSH passage model and the FLUSH transport hypotheses were not combined with the CRiSP model. In both models assumptions on transportation were expressed in terms of the post-Bonneville survival of transport fish relative to the survival of the non-transported fish that passed through the river system. This ratio, designated D, was assumed to change from year-to-year in the past, and how the ratio changes in the future is significantly different in the two models. In the CRiSP transportation hypothesis, future values of the ratio of post-Bonneville survivals of transported and non-transported fish are assumed to vary randomly about a constant, Dcrisp, that is determined from the recent transportation studies. In the FLUSH transportation hypotheses, D is determined from the passage model in-river survival using equations A.3.1-5 and A.3.2-13 (Marmorek and Peters, 1998). As a result, D, as calculated in FLUSH, is weakly related to in-river fish survival, which depends mostly on travel time.

In CRiSP D is constant, while in FLUSH D increases with decreasing in-river survival. The CRiSP model prospective analysis has slightly higher values of D. More importantly, in the

retrospective analysis CRiSP D values are about twice the FLUSH D values. The differences are a direct result of the different assumptions on the in-river survival predictions of the two passage models. The differences in D have an effect on the estimation of the intrinsic productivity of the stocks in the alpha model. It does not affect the Delta model intrinsic productivity though.

The mathematical forms of D for the two models are:

CRiSP transportation equation $D = D_{crisp}$.

FLUSH transportation equation $D = 1/[V_{barge} * (1 + a \exp(-b V_{lgr}))]$.

where $V_{barge} = 0.98$ is the direct survival in transportation, V_{lgr} is in-river survival from the tailrace of the transport dam, a and b are constants determined by regressing in-river survival predicted by the FLUSH model against T/C ratio, which is the ratio of adult returns of transported fish versus fish that passed in-river in the studies (As calculated by values provided by H. Schaller, a = 5.8259, b = 5.3533, other values were also provided but they give very similar results). For CRiSP, Dcrisp = 0.65 after 1980 and 0.18 prior to 1980. These are the average value of D calculated from T/C ratios and the in-river survival predicted by CRiSP. For prospective model runs FLUSH used data from transportation studies in the 1970s and 1980s, while the CRiSP used only the studies from the 1980s because the hydrosystem operations and the amount of descaling in the 70s were not representative of future the transportation conditions. In terms of explaining the past transportation studies, the CRiSP hypothesis assumes that the post Bonneville survival of transported fish relative to in-river fish depends on the condition of the transported fish as affected by stress associated with collection and transportation. Since fish experienced more descaling in collection prior to the 1980s (trash was not removed from the transport projects prior to 1980), for analysis of past data one ratio was used in the early years of the transport studies and one was used in the more recent years. In FLUSH the ratio of post-Bonneville survivals for all years is assumed to follow the hydrosystem survival of the in-river passing fish. The essential difference is that CRiSP seeks to explain the D by indexing it to the experience of the transported fish, while FLUSH seeks to explain the D data by indexing it to the experience of the non-transported fish.

Clarity of hypothesis

The clarity of transportation hypotheses in both model systems is low in that neither model addresses why the survival of transported fish after release from barges and trucks should be less than the survival of in-river fish. Both models use the T/C data and in river survival from passage models to estimate D. The FLUSH model derived D by first regressing in-river survival against T/C data to get a relationship that is driven by the conditions of the in-river fish and has no consideration for the effect of different transportation operations on the fish. It assumes that transportation operations had no impact on T/C and D. Improvements in fish handling over two decades of transportation are ignored. In CRiSP D is calculated using data in the 1980s and 90s, which are representative of the existing transportation conditions. By separating the T/C data into a period with trash and a period without trash at the fish collector projects the CRiSP

transportation hypothesis infers that differences between the early and later periods in D are in part due to the condition of fish in transportation.

The importance of D is that it sets the survival of the transportation fish and since most of the fish were transported D effectively sets system survival of smolts. The implications are further treated in the weak-hydro and strong-hydro aggregate hypotheses.

Weight of mechanism evidence

The FLUSH transportation model strongly couples extra mortality of transported fish only through the experience of the in-river fish. The relationship ignores changes that have occurred to the transport program over two decades of operation. This implies a strong, but unknown, coupling in which the fate of the in-river fish determine the post-hydrosystem survival of the transported fish. The mathematical consequences of this assumption become problematic when considering the system survival under specific alternatives. These problems are discussed in the critique of the system survival

The CRiSP transportation model assumes that D depends on the condition of the transported fish. It assumes the passage model accounts for the mortality of the non-transported fish. A relationship between D and the conditions of the transported fish is inferred but is not needed to estimate the D values.

Weight of empirical evidence

Both models use the existing T/C data and passage model survival estimates to estimate D. Evaluating the weight of evidence on D is contingent on the weight placed on the passage models used to estimate D and on the assumption of how D are extrapolated to the prospective analysis. The differences in the D are mostly due to the different in-river survival estimates.

Weight of prospective projections

In predicting future conditions under A1 and A2 the FLUSH and CRiSP transport assumptions give significantly different results. In CRiSP future D predictions are based on the recent transportation studies, which are assumed to represent future condition. In FLUSH future D predictions depend on changes in the in-river survival and all past D values are allowed to occur as adjusted by the frequency of the water years in which the Ds are estimated. Thus D in CRiSP is unchanged with changes in hydrosystem operations that do not directly affect the transported fish, while in FLUSH D increases with any improvement in the hydrosystem operations, upstream or downstream of the transport collection sites.

The FLUSH transportation hypothesis produces a biologically unrealistic connection between the post Bonneville survival of the transported fish in-river fish. The problem can be illustrated in terms of the system survival under the full transportation alternative A2. System survival can be simplified by noting that the number of in-river fish reaching Bonneville tailrace is small so the system survival is essentially $w = V_{transport} D$ where $V_{transport}$ is the direct survival

of transported fish from the LGR pool to the Bonneville tailrace system. System survival in the two models is

System survival A2 under CRiSP $w = V_{transport} \, D_{crisp}$.

and

System survival A2 under FLUSH $w = V_{transport} \, /(1 + m \exp(-n \, V_{lgr}))$.

where V_{lgr} is the in-river survival fish from the LGR tailrace to Bonneville tailrace and the coefficients m and n are derived from regressing the T/C data against the FLUSH in-river survival.

For CriSP, system survival then depends on the survival of transported fish down to the first dam and a random variable D_{crisp} which expresses the survival of transported fish after release from the barges. $D_{crisp} \sim 0.65$ which indicates that transported fish suffer about a 35% additional mortality after release. In FLUSH the system survival of the transported fish depends on the survival history of a handful of in-river passing fish. Thus, any change in the non-transported fish upstream or downstream of the transportation sites determines the survival of the transported fish. For example, a decreased in passage survival due an adverse passage condition at McNary Dam, would decrease transported fish ocean survival. Furthermore, the validity of the relationship in FLUSH depends on the validity of the relationship between survival and travel time. As was illustrated above FLUSH has a poor fit to data and assumption that the mortality rate changes with travel time has no ecological basis.

Table 3 Summary of transportation model evaluations.

Model	FLUSH		CRiSP	
Hypothesis	Transport effectiveness depends on in-river survival		Transport effectiveness depends on transport conditions	
Clarity	Effects of transport conditions not included in model	3	transportation conditions implicitly included	1
Mechanism	the "up-side-down logistic equation" is used to express D and it has no clear biological basis and produces illogical responses.	4	implicitly assumes D is dependent on the conditions	1
Evidence	D is neutral to T/C evidence but since D used passage model results the hypothesis suffers from the problems with the FLUSH passage model.	4	D is neutral to T/C evidence but since D used passage model results the hypothesis is supported by the strength of the CRiSP passage model	2
Validity of Projection	prospective efficiency depends on in-river conditions not experienced by transport stocks is unrealistic	4	prospective efficiency is assumed equal to existing efficiency is conservative estimator of transport effectiveness	1

3. Extra Mortality Hypotheses

Extra mortality is important to the outcomes of the actions. Generally the extra mortality is believed to occur below the hydrosystem, most likely when fish enter the estuary and the ocean. It is possible that part of the extra mortality is a result of climate conditions the fish experience as juveniles prior to migration or as adults during their spawning. To cover different possibilities and their implications, three hypotheses on extra mortality were formulated, designated as the REGIME, HYDRO and BKD hypotheses. The REGIME hypothesis assumes that the extra mortality is controlled largely by long period (decades) changes in the weather/ocean environment. It assumes the Pacific Northwest has been in a fish-unfavorable warm/dry climate regime and that the region is due to shift into a cold/wet fish-favorable climatic regime. The HYDRO hypotheses assumes that extra mortality results from stresses related to the hydrosystem and is directly proportional to the mortality of fish passing in-river. The BKD hypotheses assumes that extra mortality depends on fish health and that wild fish were infected with hatchery fish diseases, such as bacterial kidney disease (BKD), due to the large increase in hatchery production coincident with the construction of the dams. It also assumes that the infection is here-to-stay and that neither changes in the climate nor changes in the hydrosystem will lessen the impact of the disease.

Mathematically each extra mortality hypothesis is different. With REGIME and BKD hypotheses extra mortality is independent of hydrosystem changes and so it is independent of fish travel time, the number of dams, or the percent of the run transported. In the HYDRO hypotheses extra mortality depends on these parameters, and as such it depends on the passage model. Although three independent hypotheses have been formulated, so far it is possible and even likely that there are a number of processes responsible for the extra mortality. Identifying a unique source is difficult because of the concomitance of events in the late 1970s: the Snake River dams were constructed the climate switched to a warm dry regime and hatchery production increased.

Hydro hypothesis

The extra mortality from hydro related causes can be expressed in terms of the survivals of in-river fish, V_n, and the survival of fish below after passing through the hydrosystem, λ_n. Simplifying the equation it becomes

$$\lambda_n = (1 - a_y) + a_y\ V_n$$

where a_y is a year specific coefficient determined from the relationship of λ_n to V_n in the retrospective analysis. This implies that as in-river survival increases so does the post Bonneville survival. For FLUSH a_y ranges between about 0.2 and 1.4. Over all water years it averages about 0.5.

Clarity of hypothesis

The hypothesis that all extra mortality is attributed to the hydrosystem is unrealistic. Dams, increases in estuarine and river predators, changes in ocean conditions, river flow, increased hatchery production and disease are all sources of extra mortality. Attributing all these factors to a single factor is ignoring the complexity of the ecology.

The hypothesis, although simple in form, actually contains two strong relationships in that it requires that when $\lambda_n = 1$ when $V_n = 1$ and the slope of the line changes each year according to the retrospective years values of λ_n to V_n. This implies that in a prospective analysis, any change in the in-river survival from any mechanism such as drawdown, flow augmentation, or spill will follow a straight line which is defined by a single point from the equivalent retrospective year λ_n and V_n values to the point 1,1. This insures that on the average the increases in in-river survival will increase ocean survival in the models.
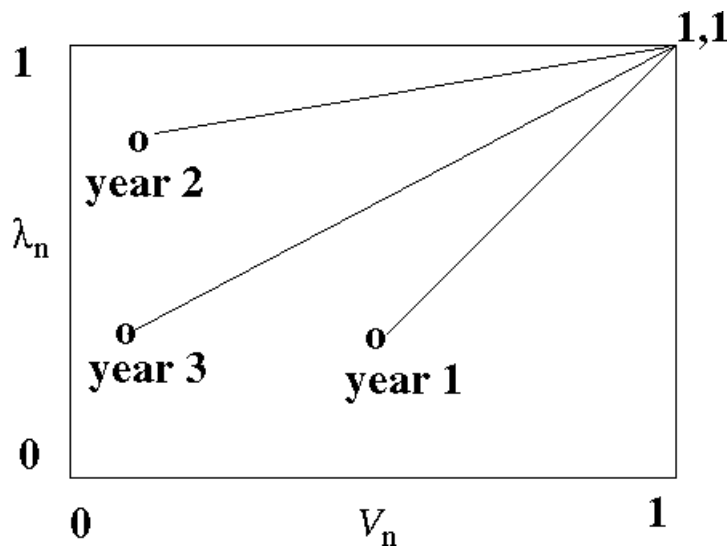

Fig. 3 In the hydro extra mortality hypothesis any change in in-river survival has a corresponding change in post hydrosystem survival that is defined by a single point and the assumption that all lines must connect to the point 1,1.

Weight of mechanism evidence

The hydrosystem extra mortality hypothesis is a tautology in which the effect of the hydrosystem is mathematically linked to ocean mortality in the life cycle equation. The yearly variations in ay only obscure the nature of the hypothesis. Functionally it can as well be held constant using the average relationship between λ_n and V_n in retrospective years. The requirement that the line intersect 1,1 is biologically mute. The condition where $V_n = 1$ for all years, is a formal statement that river mortality is zero and the effect of the river is collapsed into the Ricker a term. Statements about the effect of the hydrosystem on the extra mortality are then mute since the second point of the linear relationship defining the slope ay is undefined, so ay is undefined. Since the approach used to define the slope ay is in error an alternative approach would be to regress the retrospective values of λ_n and V_n to obtain a relationship. Hinrichsen and Paulsen did this and found no relationship.

Weight of empirical evidence

Retrospective evidence shows a flat relationship between ln and Vn and as noted above there is no prospective basis for a linear relationship. Therefore no evidence has been offered to support the hydro extra mortality hypothesis.

Weight of prospective projections

The prospective relationship for the extra mortality hypothesis is based on an erroneous model. By the model's nature it amplifies any hydrosystem action in the ocean for the survival of non-transported fish and has a mixed impact of the survival for the non-transported fish. The hypothesis was developed mathematically to attribute the stock decline to hydrosystem processes.

BKD hypothesis

The BKD hydrosystem extra mortality hypothesis simply states that the level of extra mortality observed in the past will not change by any management action.

Clarity of hypothesis

The hypothesis that all extra mortality is attributed to the disease is unrealistic. Dams, increases in estuarine and river predators, changes in ocean conditions, river flow, increased hatchery production and disease are all potential sources of extra mortality. Attributing all these factors to a single factor is ignoring the complexity of the ecology.

This hypothesis is a simplification to present the worst case scenario on reaching jeopardy and recovery standards. The underlying mechanisms was identified as bacterial kidney

disease in the wild fish. The hypothesis can represent any suite of factors that due to hatchery-wild fish interactions may have compromised the performance of the wild stock. The mechanisms could involve, genetics, BKD, competition for territory and food or other ecological processes. A better name for this hypothesis is Hatchery Effects hypothesis.

Weight of mechanism evidence

There is no clear mechanism to identify how BKD produces the mortality

Weight of empirical evidence

There is no strong evidence for this hypothesis other than the observation that BKD infection in wild fish originated from hatchery fish plus the observation that hatchery production increased concomitantly with the development of the hydrosystem.

Weight of prospective projections

The prospective projections of this hypothesis imply there is nothing else to do to the hydrosystem. Other identified sources of post hydrosystem mortality including birds and other estuary predator, plus the documented improvements in hydrosystem operations over the time frame of the retrospective period are ignored. The hypothesis that the future levels of extra mortality will follow the past pattern is unsupported.

Climate hypothesis

The climate hypothesis in the Delta and Alpha life cycle models both try and capture the effects of climate change that occurred near the time that the Snake River dams went on line. The approaches are different though, and the resulting impacts on prospective analyses are different.

The DELTA model prospective analysis selectively applies the delta values for years in dry years (1975-1990) until brood year 2006 then changes to selectively apply delta values for the earlier wet years. In the Alpha model the same prospective shift is represented by a constant shift in mortality associated with the climate change in 1977. The prospective change is taken to occur in brood year 2006. An important difference in the two approaches is in the magnitude of the shift. This depends on the particular combination of passage model and life cycle model. The underlying causes are contained in the structures of the models but the salient points are noted in Table 4.

Table 4 Main difference in the climate based extra mortality hypotheses

Model	Alpha life cycle model	Delta life cycle model
Parameter	SHIFT	δ
main hypothesis	climate shift is difference between passage survival and spawner recruit survival	climate shift is difference between upstream and downstream stocks with bias to downstream stocks
CRiSP passage model	LARGE change because CRiSP has small passage survival difference with climate shift so mortality is attributed to climate.	SMALL change because the d factor reflects the response of the lower Columbia fish to climate change
FLUSH passage model	SMALL change because the average difference between wet and dry regimes with FLUSH is small.	SMALL because the delta d reflects the response of the lower Columbia fish to climate change

Clarity of hypothesis

neither of the hypothesis is clear and both ignore other factors that have affected the extra mortality over the data set. Climate is not the only factor contributing to the extra mortality. Dams, increases in estuarine and river predators, changes in ocean conditions, river flow, increased hatchery production and disease are all potential sources of extra mortality. Attributing all these factors to a single factor ignors the complexity of the ecology.

The Delta model implicitly makes the assumption that the climate factors are equal between Snake and Lower Columbia Stocks. In actuality the way the retrospective Delta model is formulated, δ is only defined by the lower river stocks for years < 1970 (Anderson and Hinrichsen August 1 1997, PATH document). This biases the change in d with the shift in climate to follow the lower river response. In prospective analysis the model is also driven by the lower river climate change. A hardwired assumption of this Delta model hypothesis is that the up-river and down river stocks have exactly the same response to climate, even though they are in different water sheds.

Weight of mechanism evidence

No mechanisms has been identified to explain how climate shifts productivity or why the upper river and lower river stocks should have the same level or different levels of response.

Weight of empirical evidence

Comparison of the extra mortality levels of the mid-Columbia, Snake River and lower River stocks illustrates that the mid-Columbia and Snake River stocks have similar patterns while the lower River stock have exhibited less change. See Hinrichsen ( ) for details. Since the mid-Columbia stocks have not had significant changes in their hydrosystem during the retrospective period this is evidence that the upper river stocks has responded more strongly to

climate change than the lower river stocks river stocks. Unfortunately although they were analyzed in the Alpha model, PATH choose not to consider the mid-Columbia stocks.

Weight of prospective projections

Prospective projections based on these differing climate models need to be reevaluated and separated in the aggregate hypothesis the results of CRiSP-Alpha model from the FLUSH-Delta model results. Mixing Alpha and Delta model results diminishes the effect of the true climate hypothesis.

Alternative hypothesis

The sensitivity analysis in PATH has identified two alternative hypotheses that are internally consistent and lead to different outcomes. These are the strong-hydro and the weak-hydro hypotheses.

Strong-Hydro = FLUSH/TRANS1, worst-cast passage assumptions, delta model, hydro-related extra mortality/ Markov climate, and most favorable drawdown assumptions.

Weak-hydro = CRiSP/TRANS4, best case passage assumptions, alpha model, regime shift extra mortality least favorable drawdown assumptions.

The important survival measures of the two aggregates can be characterized by the product of three terms:

$$w * \lambda_n * f(climate)$$

These are passage survival (system survival) times the post hydrosystem survival (extra mortality) of in-river passing fish for a given water year times a climate factor. To illustrate the differences between the two aggregates a number of simplifications can be made that do not affect the dependence on the critical assumptions related to the passage models, transportation and the extra mortality. These simplifications and definitions are as follows:

- Under full transportation (A2) all fish are transported so $P = 1$.

- Survival in transport is V_t

- Survival to the transport dam from LGR pool is V_n (1)

- Survival of non-transported fish from LGR pool to Bonneville tailrace is V_n (8)

- Survival of non-transported from the transport dam to Bonneville tailrace is V_n (7)

- Survival of non-transported from the MCN tailrace to Bonneville tailrace is V_n (4)

- Under drawdown (A3) survival down to McNary dam is 100%

The drawdown and full transport alternatives under the hydro and non-hydro hypotheses can be expressed.

FLUSH strong-hydro aggregate hypothesis combined survivals

A2 transportation

$$w * \lambda_n * f(climate) = V_{flush} (1) ((1 - a_y) + ay\ V_{flush} (8))/(1 + a\ exp(-b\ V_{flush}(7))) exp(\delta)$$

A3 drawdown

$$w * \lambda_n * f(climate) = (1 - a_y)\ V_{flush} (4) + a_y\ (V_{flush} (4))2\ exp(\delta)$$

CRiSP weak-hydro aggregate hypothesis combined survivals

A2 transportation

$$w * \lambda_n * f(climate) = V_{crisp} (1)\ V_t\ D_{crisp}\ exp(-STEP)$$

A3 drawdown

$$w * \lambda_n * f(climate) = V_{crisp}(4)\ exp(-STEP)$$

The strong and weak hypotheses are very different in their treatment of survival. The strong-hydro related hypotheses links both transportation and drawdown survival to passage survival of in-river fish as defined by the FLUSH model which in its essential form is

$$V_{flush}(N) = B (A / (exp(B\ t) + A) - 1)\ S_{dam}^{N}$$

where A and B are determined from the fitting the equation to the Sims and Ossiander data supplemented with the PIT tag data and N is the number of dams the fish pass with dam passage mortality of Sdam and t is the travel time. The weak hydro hypotheses is based on the CRiSP passage model which in its essential form is

$$V_{crisp}(N) = \exp(-C\,t)\,S_{dam}{}^{N}$$

where C is the average rate of mortality in passage.

The two climate factors have different contributions to the survival. The d term in the strong-hydro aggregate hypothesis is cyclic with a minor contribution to variations in productivity and a long-term average is zero. In the weak-hydro aggregate hypothesis the STEP function has a larger contribution to improving survival and it goes through a step change in the next decade and has a decadal period.

Clarity of hypothesis

Neither aggregate hypotheses address the list of important factors that are have significance in the decline and recovery of the stocks. The strong-hydro hypothesis is the most restrictive, since it directly attributes the river and ocean decline to the survival of in-river fish. It specifically requires that any change in the hydrosystem also alter the extra mortality in the estuary and the ocean. The weak-hydro hypothesis is less restrictive. It estimates the hydro related mortality to river passage and combines the remaining extra mortality into a single variable STEP. Neither hypothesis directly deals with effects of hatcheries or estuarine predators and how changes in management of these factors may alter recovery. Both strong-hydro and weak-hydro aggregate hypotheses agree that there is a detrimental effect of the hydrosystem on transported fish. They disagreement on the magnitude of the effect and how alterations of the hydrosystem will affect the total survival.

In the strong-hydro hypothesis the impact of the hydrosystem is explicitly coupled to in-river survival of non-transported fish. So any change in the survival of the non-transported fish changes the survival of the transported fish. This produces ecologically unrealistic responses for the A1/A2 hypotheses involving transportation and the A3 involving drawdown. For A2: Survival of transported fish in the ocean is defined by the in-river survival of the non-transported fish. For A3: Survival of fish in drawdown alternative in the ocean depends on the survival in the river. In the weak-hydro hypothesis under A2 transported fish suffer an additional extra mortality in the ocean but the level and variations are not fixed to the experience of the non-transported fish. For drawdown (A3) the extra mortality of fish is independent of the in-river experience.

Weight of mechanism evidence

The strong-hydro hypothesis explicitly, connecting the survival of ocean fish with the river survival has no mechanistic basis. This is especially true for the A2 alternative since

transported fish do not pass through the river but in the hypothesis their survival in the ocean is defined by river conditions. For A3 in the strong-hydro hypothesis, any benefits in the river are amplified in the ocean by an unstated mechanism.

Evidence for the strong-hydro hypothesis does not distinguish the differences of the in-river and transport routes of passage. It is a mixed qualitative list of river factors and provides no support why survival should be directly connected to a specific in-river survival formula that is strongly influenced by two outlier low flow years. The weak-hydro hypothesis on A2 accounts for an effect of the hydrosystem on transportation according to the transport studies through the estimations of Dcrisp.

Weight of empirical evidence

Empirical evidence required to support the strong-hydro hypothesis is flawed. The strong travel time survival relationship of FLUSH is not supported by data or mechanisms. The assertion of an explicit connection between extra mortality of both transport and in-river fish to in-river survival is has no mechanism nor empirical support as discussed in the section on extra mortality and by Hinrichsen and Paulsen. The only intuitive evidence of the strong-hydro effect is the observation that the lower river stocks have not exhibited the same level of decline as the upper river stocks and this evidence is only relevant if the two stocks have the same encounter and response to climate/ocean conditions. In fact since the freshwater habitats of the upper and lower river stocks are significant different their experience with climate prior to smolt migration are different. Furthermore the extra mortality of the mid-Columbia stocks exhibits a pattern similar to the Snake stocks but without a change in the number of dams that fish pass during their migration. Thus the surmise that the climate effects are identical is unsupportable.

Weight of prospective projections

The strong-hydro hypothesis projects that stock recover by the removal of dams and decreasing of travel time of fish. This projection uses a system of equations that amplify the impact of river survival on over all survival. It excludes all other potential factors as being relevant to recovery. The weak-hydro hypothesis projects stock recovery by changes in climate. The two hypothesis bracket the effects of climate and the hydro but neither hypothesis comes close describing the ecological reality that has contributed to the stock declines and the actions that are needed for their recovery.

Table 5 Summary of aggregate hypotheses evaluations

Hypothesis	strong-hydro		weak-hydro	
	transport and drawdown survivals in ocean and river are all directly linked to in-river survival		decouples survival of transport and in-river fish in river and ocean	
Clarity	Implications and response of the model are opaque because of linkage to in-river survival regressions. Other factors affecting survival are implicit in the functional forms relating survivals to in-river. Assumptions affect estimates of intrinsic productivity of system.	3	Implications and response are clear. Other factors affecting survival are implicitly contained in the extra mortality. Assumptions also affect estimates of intrinsic productivity of system.	1
Mechanism	Mechanism for strong coupling not stated	4	Unlinked coupling between mortalities	1
Evidence	Weak evidence since FLUSH model is not supported by evidence	4	Moderate evidence because CRiSP model is supported by evidence	2
Validity of Projection	The model illustrates the maximum possible influence of the hydrosystem. It does not account some important factors.	4	The model illustrates mixed effects of the hydrosystem and climate. It does not account some important factors.	1